Context-based Chemistry: Creating opportunities for fluid transitions between concepts and context

By Donna King

Nationally and internationally, context-based programs have been implemented in an attempt to engage students in chemistry through connecting the canonical science with the real world. In Queensland, a context-based approach to chemistry was trialled in selected schools from 2002 but there is little research that investigates how students learn in a context-based setting. This paper presents one significant finding from an ethnographic study that explored the learning that occurred in an 11th grade context-based chemistry classroom in Queensland. The study found that by providing students with the opportunity to write, fluid transitions (or to- ing and fro-ing) between concepts and context were an outcome of context-based learning.

Introduction

Over the last two decades reports have traced students' increasingly negative attitudes to Science in Australia over the middle years of schooling, and the associated decrease in student participation in post- compulsory science (Goodrum, Hackling, & Rennie, 2001; Tytler, 2007). This decline in interest in Science in the early years of secondary education is of particular concern, since it is in these years that attitudes to the pursuit of science subjects and careers are formed (Speering & Rennie, 1996). A number of studies have explicitly linked this decline in student interest with the nature of the traditional science curriculum and its inability to make science meaningful and interesting to students (Fensham, 2004; Lyons, 2006). By making Science more relevant to a broader audience we can prepare prospective science degree students and professionals, as well as contribute to improved scientific literacy for all students.

New approaches to the teaching of Science have been tried in the last ten years and research has been undertaken to look at ways of improving the way in which we teach school Science (Millar, Leach, & Osborne, 2000; Roth, 1995; Tobin & McRobbie, 1995). In particular, chemistry teaching is one area that has undergone significant reform in an attempt to make Science more relevant for all students (Barber, 2000; Beasley & Butler, 2002; De Vos, Bulte & Pilot, 2002; Gabel & Bunce, 1994; Gutwill-Wise, 2001; Ramsden, 1992, 1997; Tobin & McRobbie, 1995). Context-based Chemistry has been implemented in international Chemistry programmes (e.g. Chemistry in Context in the USA, Salters in the UK, Industrial Science in Israel, Chemie im Kontext in Germany and Chemistry in Practice in The Netherlands) throughout the last decade and has been trialled more recently in Victorian and Queensland classrooms here in Australia. This new approach to teaching chemistry was designed to address issues such as students' lack of engagement in chemistry and decreasing participation rates.

In Queensland, the new Chemistry syllabus using the context-based approach has been on trial in schools since 2002, and the trial-pilot syllabuses in chemistry and physics were published in September 2004 by the Queensland Board of Senior Secondary School Studies. Despite recent changes, with the current syllabus mandating the inclusion of only one context (or one Extended Experimental Investigation (EEI)) in the Queensland chemistry syllabus, teachers may choose to continue to teach all chemistry units in context. Context-based approaches represent a significant change in the teaching of chemistry. This paper presents one outcome of a larger study conducted in a Year 11 context-based Chemistry classroom in Queensland.

Background

Despite several interpretations of the context-based approach to teaching (see, for example, King, 2007), in this study it refers to teaching episodes with a primary focus on the application of chemistry to a real-world situation. Chemistry is taught when the students require the knowledge for further understanding of the real- world context. An instructional framework that prioritises learning through students' inquiries should embody a 'need-to-know' principle where the context legitimises the learning of chemical theory from the perspective of the students and thus makes their learning both extrinsically and intrinsically meaningful (Beasley & Butler, 2002; Bulte, Westbroek, de Jong & Pilot, 2006).

International research on context-based teaching reveals that context-based Chemistry education helps students see and appreciate more clearly the links between the Science they are studying and their everyday lives (Hofstein, Kesner & Ben-Zvi, 2000; Wierstra & Wubbels, 1994); that students' interest in and enjoyment of their science lessons generally increase when they engage in context-based courses (Barber, 2000; Gutwill-Wise, 2001; Parchmann et al., 2006; Ramsden, 1992, 1994, 1997); and that students following context-based courses learn science concepts at least as effectively as those following more conventional courses (Barber, 2000; Smith & Bitner, 1993; Wierstra, 1984).

In Australia, the small body of research on context- based approaches has been carried out in two States, Victoria and Queensland. While the literature confirmed prior research that relevance to real life and increased motivation were advantages of the context-based approach, teachers were concerned that students were unable to transfer their learning and apply concepts in situations outside the context in which they were learned (Vignouli, Hart & Fry, 2002; Wilkinson, 1999). In contrast, a study by King, Bellocchi and Ritchie (2008) showed that there is some evidence that connections between concepts and contexts, within a context, are an outcome of context-based teaching.

Assessment has also been problematic for Australian teachers since flexibility in choosing contexts, along with the inclusion of more open experimental investigations (such as the EEI), have made teaching a common body of knowledge difficult (Hart, 1998). Consequently, States such as Victoria reverted to traditional teaching to prepare students for external assessments. Since the Queensland school system does not assess through external examinations, there is more freedom for teachers to choose contexts, but there is a lack of clarity among teachers about what constitutes context-based teaching (King, 2007; Wilkinson, 1999). This confusion, along with the results from the literature, revealed a need for additional fine-grained studies on context-based teaching. The way in which the context- based approach was implemented in an actual chemistry classroom was the principal focus of a larger study. This paper presents one key finding from the larger study which highlights how learning occurred in the context-based classroom.

Research Method

I employed an interpretive methodology using ethnographic techniques for this study (Erickson, 1998; Merriam, 1988; Stake, 1994), which was conducted during one three-month term (March to May) in 2006 in an 11th grade chemistry class at 'St. Anthony's' (a pseudonym), an independent boys' high school in Queensland, Australia. The students were in their second term of chemistry studying a unit on water. The average age of the students was 15 years and 9 months. Students were predominantly from middle- to upper-class families.

A single case study design was chosen to explore the transactions that occurred in the classroom (Bassey, 1999; Erickson, 1998; Merriam, 1988). By choosing an individual case I developed a deeper understanding of the interactions in one context-based classroom. Fine-grained analysis of the data provided a clearer understanding of how the learning occurred for the students (Stake, 1994).

Data Collection

Data were derived from field notes and analytic memoranda based on observations of the classroom, with a particular focus on two selected groups of students; the teacher in whole-class interactions; and interactions between the teacher and the selected groups. Other data sources included classroom documents, student journals, interviews with students and their teacher, and video and audio recordings of teacher and students. My analytic process began with the transcription of all recorded lessons, interviews and in-class interactions. Themes were distilled from the initial review of the relevant literature, as well as content analysis of project work. While four assertions structured the outcomes of the whole study, this paper presents one significant finding from the larger study that highlights the learning that occurred when students were provided with the opportunity to write a report on the water quality of their local creek ('Yabbie Creek' –a pseudonym).

Selection and categorization of participants

I invited the teacher to identify two groups of students for the purposes of detailed classroom observations and interviews about their activities. She determined the groups based on their academic results from the previous term's work, as well as their cultural backgrounds. I did not have access to the results but I was confident that she would choose contrasting but representative groups from her chemistry students. Group 1 consisted of 'Mark', 'Shane', 'Peter' and 'Ryan' (pseudonyms). Group 2 consisted of 'Richard', 'Ned', 'Dave' and 'Charles' (pseudonyms). Although the teacher was still getting to know these students, having only taught them for one term, she suggested that four of these students (Mark, Shane, Richard and Ned) were average or above average on the chemistry assessment completed so far; three students (Ryan, Charles and Peter) were identified as needing some assistance with understanding chemistry concepts; and one student (Dave) was identified as needing a consirable amount of assistance to complete set chemistry tasks. Peter and Dave were Chinese- Australian students. Peter had come to St. Anthony’s from another school to complete Years 11 and 12. In a subsequent interview he told me that this was so that he could get a better OP score (Overall Position - the score that determines university entrance) at the end of Year 12. Dave had spent time in the international college affiliated with the school prior to attending mainstream classes at St. Anthony’s. Once the study was underway, two extra students, George and Aaron, became part of the study due to their interest and willingness to be included. The table below summarises the students in the larger study:

Table 1) Composition and class achievement of students in focus groups.

GROUP 1	**GROUP 2**	**EXTRA STUDENTS**
Mark (Sound Achievement)	Richard (High Achievement)	George (High Achievement)
Shane (Sound Achievement)	Ned (Sound Achievement)	Aaron (High Achievement)
Peter (Low Achievement)	Dave (Low Achievement)	
Ryan (Sound Achievement)	Charles (Sound Achievement)	

I categorised the students’ work into three rankings (as seen in Table 1) which were checked for reliability with two Chemistry educators. These categories (high achievement, sound achievement and low achievement) do not necessarily correspond with the Queensland categories of Very High Achievement (VHA), High Achievement (HA), Sound Achievement (SA), Low Achievement (LA) and Very Low Achievement (VLA). Rather, high achievement refers to a student demonstrating above average results, sound achievement refers to a student demonstrating average results and low achievement refers to a student demonstrating below average results. These rankings were based on my assessment of the quality of their written reports submitted at the end of the unit and conceptual understanding demonstrated in a final interview at the end of the unit. The rankings differed marginally from the final grades given by the teacher, since the teacher only used the written report for rading (see Appendix 1).

Positioning students according to categories can be problematic. In particular, I found the ‘sound’ category encompassed a broad range of abilities. Consequently, data for this category were the most difficult to rank compared to the other two categories. Students’ work in the ‘sound’ category represented both the upper and lower ends of this range. In Appendix 2, I have included one example of the categorisation of ‘sound- achieving’ students.

The water unit

Prior to implementation, the teacher and the author met on four occasions to design the water unit. One of the main goals during the design process was to maintain the centrality of the context (i.e. the water pollution of the local creek) in the classroom processes. The assessment task had been previously determined for the unit through the school work programme; that is, the students were required to complete an Extended Response Task (ERT) or, more simply, a written report. The ERT required the students to complete three phases; firstly, research each water quality test in groups; secondly, complete the tests (see Appendix 3) using three water samples collected from three sites at the local creek (i.e.Yacht Club, Sewerage Treatment Plant and the mouth of Yabbie Creek) and thirdly, write the report. Step three, the focus of this paper, is detailed in Appendix 4. This was the first unit in Chemistry undertaken by the students that required them to connect laboratory test results (primary data) to a real-world context. Prior to this they had completed a unit on the bonding of metals and ionic compounds which did not involve the analysis of primary and secondary data.

The teaching sequence the teacher and I designed was informed by state-mandated requirements and supplementary material gleaned from a review of international developments in context-based approaches (e.g. Beasley & Butler, 2002). This teaching sequence was planned to elicit key questions from the students through an introductory activity. Following this, the questions were answered through investigative laboratory work (predominantly traditional water quality experiments) and analysis of the results, and content was taught as the students required the knowledge. Finally, the students applied the knowledge to writing a report and making decisions about the water quality of the local creek by comparing their results with the water quality standards. While an in-depth explanation of the teaching approach is not the subject of this paper, it can be summarised briefly as an approach designed to keep the context central to all class transactions. A flowchart summarising the steps forms Appendix 5.

Fluid transitions

As the study evolved, I became aware of evidence in the written and oral data that students were linking science concepts to the context. I chose to use the term 'fluid transition' to define instances where the students spoke or wrote about how the chemistry applied to the context (i.e. the local creek). This metaphor originated from work by Beach, who defined a collateral transition as involving individuals' relatively simultaneous participation in two or more historically-related activities (Beach, 2003). He further explained that collateral transitions involve back and forth movement between activities and hence are multi-directional. Beach's metaphor of 'transitions' can be elaborated further to the term 'fluid transitions' to describe the back and forth movement (or to-ing and fro-ing) between concepts and contexts that can occur when students are learning in a context-based chemistry classroom. Even though the students may not physically move between the classroom and the real-world context, their conversations and written work move back and forth between canonical chemistry and the context. Therefore, the metaphor of 'fluid transitions' is used in this study to refer to instances where the students talked or wrote about how the chemistry applied to the real-world context. This paper presents only the written component of the study.

To further explain how fluid transitions were determined, I have included an example of the data analysis in Appendix 6.

Results

Assertion: Fluid transitions were realised in the written activities

I searched the data for instances and non-instances where the discourse of Science was used in a canonically accurate form to explain the water test results through comparison to standards. At the same time, I searched for merging discourses of canonical chemistry with the pollution at Yabbie Creek. Canonical accuracy was a pre-requisite for fluid transitions between concepts and context. In other words, for 'fluid transitions' to be present, the student must firstly analyse the results compared to standards and make accurate canonical inferences about the quality of the water, and secondly, explain causes of pollution based on the analysis of the results.

I now present a small body of evidence from two students, George and Shane, where I found fluid transitions in the written activities, namely the ERTs.

GEORGE (High Achiever)

George came into the class with previous academic success in Science. He had been involved in an extension Science course in Year 10 and had undertaken water analysis in this advanced class. George was categorised as a high achieving student and his written and oral work displayed a high level of canonical accuracy. In the ERT, George summarised comprehensively the 10 water test results and their comparison to water quality standards. Not surprisingly, the data for George wer replete with examples of fluid transitions, which were found on 20 occasions in the ERT and eight occasions in the follow-up interview. For George, both the written task and interview afforded him the opportunity to demonstrate connections between the chemistry concepts and the context of the creek. This first excerpt from George's ERT demonstrates his strong written skills in outlining the pollution at Site 1 (Yacht Club), and illustrates fluid transitions between concepts and context:

> All the above indicators ultimately make the overall water quality at the Yacht Club poor. Another piece of information to consider is the fact that not far up Yabbie Creek there are sewerage outlets which may cause the faecal coliform counts to be high. According to these test results, high algal photosynthetic activity seems to be in progress in the water. I say this because scores over 110% in saturation in the dissolved oxygen test indicate algal photosynthetic activity. I suggest the water only be used for boating and nothing else. (Written Report, p. 2)

In the opening sentence George connected the water test results with the context of the local creek by writing, all the above indicators ultimately make the overall water quality at the Yacht Club poor. The data from laboratory tests which had been summarised in the written report substantiated this claim. Following this, George demonstrated fluid transitions with the real-world context when he connected the cause of the pollution to the high faecal coliform count in the sewerage outlets, and linked the saturation results to algal photosynthetic activity in Yabbie Creek. The reference to 'scores over 110%' was canonically accurate since results greater than 110% saturation indicate that algal photosynthetic activity is producing a super saturation of dissolved oxygen (Smith, Monteath, Gould & Smith, 2006). In comparison to those of the other nine students in the study, George's ERT exhibited a high level of canonical accuracy.

While George may have developed good analytical skills in junior Science classes, as well as through his involvement in a previous extension class, this study shows that on this occasion, in the context-based water unit when he was required to write an ERT, his written work demonstrated fluid transitions between concepts and context.

SHANE (Sound Achiever)

In Shane's written report there were 23 examples of fluid transitions between concepts and context but also five examples of a lack of connections, or rather, when the discussion lacked canonical accuracy and incorrect inferences were made about the causes of pollution. I will begin this analysis with a summary paragraph written by Shane, which is representative of his three conclusions for each of the three sites in his ERT:

> Sample 1 has failed five out of the possible eight criteria that have been used to test the water quality of each sample. This water contained unacceptable amounts of nitrates, phosphates, faecal coliform, total dissolved solids, and turbidity, and only passed in dissolved oxygen, biochemical oxygen demand, and pH. Water quality is rated as polluted if it fails in one or more criteria. Since Sample 1 has failed five of the criteria, it can be rated as polluted. (Written Report, p. 2)

In the above paragraph, fluid transitions occurred when Shane linked the test results with the water quality of the creek. The statement, since Sample 1 has failed five of the criteria, it can be rated as polluted represented a link between the test results and the context of the creek. Similarly, Shane summarised the test results to explain the water quality at Sites 2 and 3, concluding that the water at Yabbie Creek was 'highly polluted'. Shane's accurate comparison of the test results to the water quality standards demonstrates transitions between the canonical science and the context.

There were, however, five occasions on which Shane wrote the same canonically-inaccurate statement in his ERT. This occurred when he wrote an explanation for the turbidity values for the three samples. The following summary explaining the cause of pollution contained a misconception about the contribution of the nutrients to the turbidity of the water:

> As the water flows down the creek, so do the nutrients. As they arrive at the mouth of the creek, from where Sample 1 was taken, they start to settle. This also causes the polluted turbidity value, as there are many nutrients floating in the water. (Written Report, p. 2)

He also commented further:

> This water is likely to be carrying nutrients such as nitrates and phosphate. These nutrients then sink to the floor of the creek as they come from the plant. Over time, underwater animals are drawn to these nutrients and after they consume them, they excrete and produce faecal coliform. The nutrients and faecal coliform in the water cause turbidity, as they are

> suspended solids floating in the water. (Written Report, p. 3)

The nutrients do not contribute to the turbidity since they are dissolved ions in the water. Also, faecal coliforms are bacteria or micro-organisms that are so small they do not affect the turbidity reading of the water. Despite a canonically accurate scientific definition of turbidity in Shane's ERT, on five occasions he could not apply this information with accuracy. However, he was still ranked as a sound achiever because he gave 23 accurate connections between concepts and context in the written report and interview, and the five inaccurate connections all related to one misunderstanding - of the term 'nutrients'. Surprisingly, when Shane was questioned about turbidity in the interview he gave a scientifically accurate response:

> Researcher: OK can you explain to me what is turbidity?
>
> Shane: The amount of suspended solids in the water, the clarity of the water.
>
> Researcher: You wrote a lot about turbidity and the comparisons with government results. Could you explain the factors contributing to turbidity results?
>
> Shane: Yeh, I think one of them is flow like current, they might have taken their results when something was stopping the current like a tree or something and then that would slow down the current and more solids would build up instead of flowing through the river. (Final Interview, 9/6/06, p. 2)

In this interview excerpt, not only did Shane give an accurate definition of turbidity, he also applied it to the real-life scenario of the local creek. When he said:

> something was stopping the current like a tree or something and then that would slow down the current and more solids would build up instead of flowing through the river.

In this case, Shane was to-ing and fro-ing between the water quality parameter of turbidity; that is, a measure of the amount of suspended solids in the water, and the real-world context of the creek. In this one instance, Shane could articulate the connections between the concepts and context more accurately than he could write them. Similar results were found for the other four 'sound-achieving' students.

This was the first unit in Year 11 chemistry that required the students to analyse primary data, compare them to secondary data and write a report. I have presented a small part of the evidence gleaned from the larger study that shows despite some instances of canonical inaccuracy, the 'sound- achieving' students demonstrated fluid transitions in the written task.

DAVE and PETER (Low-Achieving Students)

Dave and Peter were exceptional cases less likely to be found in many other chemistry classrooms; that is, they were atypical international students whom the teacher described as 'extremely weak'. In a subsequent year, she reflected on her Year 11 Chemistry class and referred to the academic ability of the international students as being 'really strong'. However, in this study, the analysis of the data for the low-achieving students, Dave and Peter, revealed that the written task did not afford them the opportunity to demonstrate to-ing and fro-ing between concepts and context. An assessment such as the ERT disadvantaged Dave and Peter, whose first language was not English. Here I found a contradiction to the assertion that fluid transitions between concepts and context were not realised in Dave's and Peter's written activities. More research needs to be conducted with ESL students in context-based chemistry classes to better explore and understand the challenges they face. Suggestions for helping students who have English as a second anguage follow in the conclusion.

Conclusion

As Australia moves towards a national curriculum, it is becoming even more important to highlight the implications of a Science curriculum that has personal value and relevance to students. Connections between concepts and contexts enable students to see the relevance of chemistry to their everyday lives. The results of this study support prior research that students' connections between concepts and contexts are enhanced through context-based teaching (King et al., 2008). Although this does not alleviate teachers' concerns about the problems many students have in transferring knowledge from one context to another (Hart, Fry & Vignouli, 2002; Wilkinson, 1999), it is encouraging that students are able to make the important connections within a context-based unit. One practical suggestion from this study is to encourage teachers to choose contexts that enable concepts to be revisited in different contexts. This may help students to see connections between concepts and a range of real-world applications. For example, the solubility of ions in solution could be taught in the water quality context when discussing conductivity of water, hardness of water or removing ions by precipitation. In a subsequent unit on 'Shipwrecks' (a context-based topic that incorporates the chemistry of corrosion and gas laws) solubility could be revisited when discussing how iron as a metal becomes an ionic compound in salt water during the formation of rust.

In this study, fluid transitions occurred for the sound- and high-achieving students when they were afforded the opportunity to write a written report that analysed the pollution in the local creek. Even though the students did not appear to appreciate fully that the creek was situated in the broader context of the local community, since they had not collected the water samples themselves, their classroom conversations showed evidence of to-ing and fro-ing between the canonical science and the context.

The low-achieving students, who were unlike international students taught in a subsequent Chemistry class at St. Anthony's, had English as their second language and did not make fluid transitions between concepts and context. Further research is required to answer the question: How do we help students on the margin succeed in context-based chemistry where strong literacy skills are required? Tobin and McRobbie (1996) suggest ESL students need opportunities to use their 'mother tongue' in chemistry classrooms as well as to have access to chemistry texts written in their own languages. Also, because of the importance of speaking and making sense of oral discourse, the provision of opportunities for ESL students to participate in courses to improve their speaking of English and comprehension of spoken English ought to be a priority. Additional resources, such as an interpreter or multi- lingual teachers and teacher aides, in the classroom may help students with English as a second language to comprehend the discourse in the classroom as well as in their written work.

So in conclusion, why do we choose to teach Chemistry contextually? I would argue that one outcome of context-based chemistry is the application of it to important real-world issues such as the environmental pollution of the local creek. Furthermore, a real-world focus may increase motivation, enjoyment and the appreciation of the relevance of Science. This study has shown that by teaching Chemistry contextually and affording students the opportunity to write a report, teachers can provide them with the knowledge and skills to make connections between science concepts and context. This was achieved in this study through a pedagogical approach that prioritised the context. The contraction of the current context-based syllabus to only one context (or one EEI) in the most recent amendment to the Queensland chemistry syllabus, may make alternative pedagogical approaches to this one context more achievable for teachers. Incorporating a written report in a unit that centralises learning around a real-world context is one way of encouraging connections between concepts and context in context-based Chemistry.

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Appendix 1

Table 2. Year 11 Chemistry Class Rankings by Teacher and Researcher

Student	**Teacher Rankings**	**Researcher Rankings**
George	#B++	*HA
Peter	C--	LA
Ryan	C-	SA
Dan	D+	LA
Mark	B-	SA
Aaron	A+	HA
Shane	A-	*SA
Richard	#A--	*HA
Charles	B-	SA
Ned	B+	SA

* Differences due to the inclusion of interview comments for rankings by researcher.

#While A--and B++ are almost indistinguishable, the teacher ranked Richard ahead of George for achievement in this task.

Appendix 2

Sound Students had inconsistent of variable responses across written and spoken forms of data generation

For example, the following short excerpt was classified as canonically accurate:

> The average pH reading of Sample 1 was 8.225.Being above 7, the water is considered to be alkaline. (Written Report, p. 2)

Any pH reading above 7 is alkaline so the excerpt contained a canonically accurate scientific statement. Also, the value of 8.225 gave a measure of alkalinity. The student's interpretation of the reading as alkaline was accurate. In contrast, an example of a statement that was categorised as canonically inaccurate follows:

> pH is the temperature of the water turbidity. (Final Interview, 13/6/06)

Clearly, this statement is inaccurate since pH is a measure of the acidity or alkalinity of a sample. These two examples were categorised with ease, however, there were occasions when the sound-achieving students would give a canonically accurate definition of the water test but an inaccurate explanation for the cause of the pollution. The following example demonstrates this:

> The water has large amounts of phosphates, nitrates and metals (magnesium and calcium), possibly coming from the oil and waste from the boats. (Written Report, p. 2)

The student gave canonically accurate definitions for all the water tests, as well as accurate comparisons to standards, prior to writing this conclusion. However, large amounts of phosphates and nitrates in the creek are more likely to be due to the run-off from fertilisers used on land rather than oil and waste from boats. A minor error such as this was overlooked in the achievement ranking if the rest of the work was canonically accurate. This is an example of a sound-achieving student's work that gave inconsistent or variable responses across written and spoken forms of data generation.

Appendix 3

Table 3. Summary of Water Tests

Test	Explanation	Unit of Measurement
pH	pH meter was used to measure the pH of samples	
Turbidity	Turbidity tube: a long, thin clear, plastic tube, sealed at one end with a white plastic disc with three black squiggly lines on it. The tube has a scale marked on the side, reading from 10 to400 NTU.	NTU: Nephelometric turbidity units
Temperature	Thermometer was used to measure temperature	Degrees Celsius
Conductivity	Conductivity meter was used to measure amount of total dissolved salts	Microsiemens per centimetre
Total dissolved solids	Suspended solids were filtered and then the sample was evaporated to dryness and the remaining solids weighed.	mg/L
Dissolved oxygen (DO)	Dissolved oxygen testing kit was used. DO was measured by Winkler titration (a chemical analysis technique) of water samples.	mg/L or % saturation
Biochemical Oxygen Demand (BOD)	This is calculated by carrying out the dissolved oxygen test after five days. The amount of DO on day five is subtracted from the amount of DO in the DO sample bottle on day 1.	mg/L
Faecal coliforms	Faecal coliforms were filtered from the water and cultured in a petri dish in an incubator for 24 hours.	CFU (Colony-forming units) /100ml
Water hardness	Tablets were added until a colour change appeared or mg/L	ppm (parts per million)
Nitrates	Nitrate testing kits were used which required students to add a reagent to convert nitrates to nitrites and interpret colour changes using a colorimeter	ppm or mg/L
Phosphates	Test kit used. Colorimeter was used to determine the concentration of phosphates after the addition of reagents to produce a coloured solution for analysis.	ppm or mg/L

Appendix 4

Phase 3 of the Task Sheet 'Rating the water quality of Yabbie Creek'

Phase 3: Writing the report (Individual work)

Write a report to the Yabbie Creek Residents' Environmental Protection Group summarising your investigation, results and conclusion. Your report should consist of the following sections:

Conclusion and Discussion

Address your conclusion to the Residents' Environmental Protection Group. Your conclusion should include the following points:

- You should interpret your results - how you would rate the water quality at each of the three sites? Is Yabbie Creek affected by the sewerage treatment works? You should justify your interpretations and explanations thoroughly.
- Compare the experimental results with water quality test results in available literature such as local and state government documents.
- Comment on any unusual, unexpected or interesting results.
- Where appropriate, provide recommendations
- Which will improve the water quality of Yabbie Creek.

Evaluation

- Identify sources of experimental errors
- Discuss the limitations of the results and conclusions generated in your investigation. For instance, discuss the validity of the sampling methods, the relevance of each water quality indicator and the validity of the testing methods. Are your conclusions strongly supported or would you recommend that more evidence is required?
- Suggest how the investigation could have been improved and provide reasons why.
- Suggest logical future research possibilities, including further tests, relating to your investigation. Justify your suggestions.

Appendix 5

Context-Based Model

(Beasely & Butler, 2002)

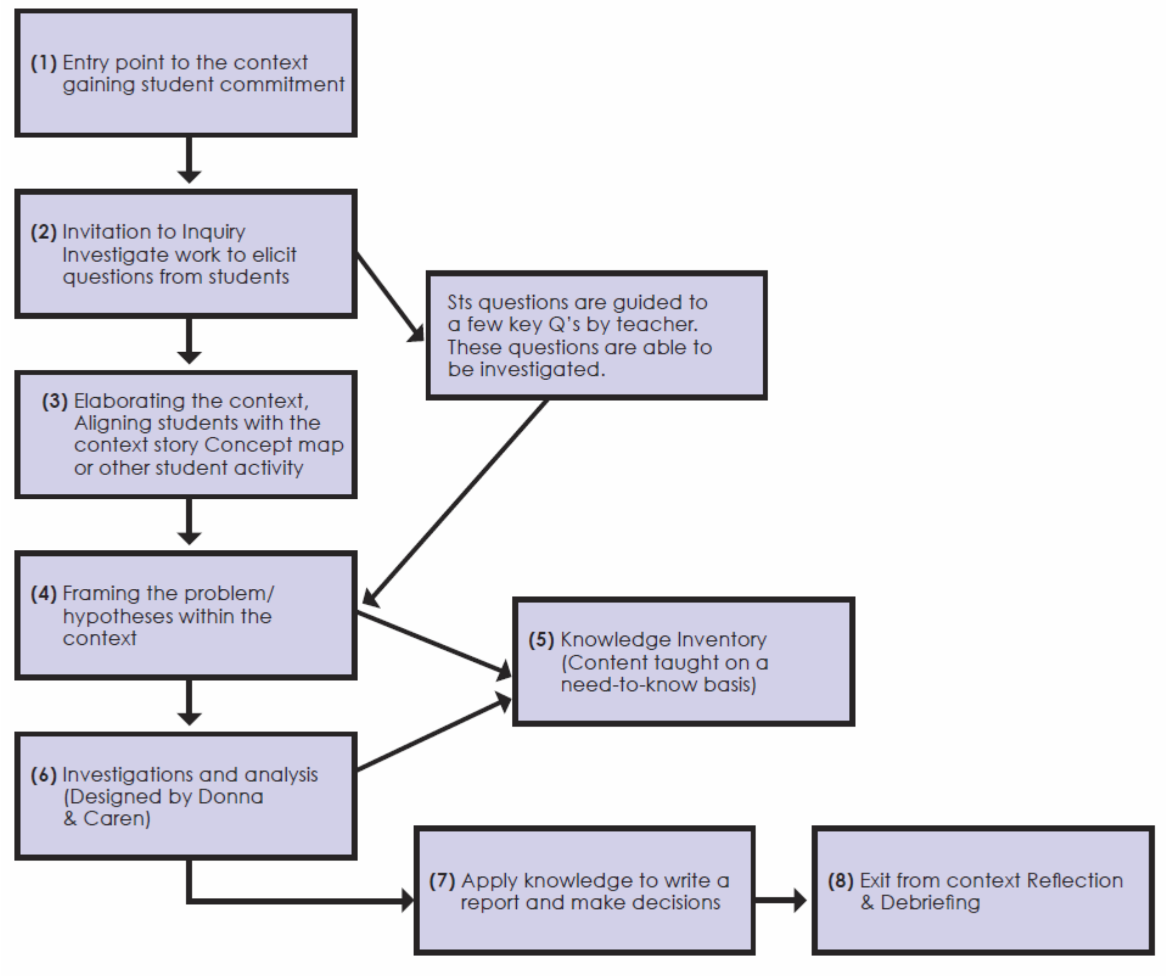

Figure 1. A model showing the possible steps for a context-based chemistry unit (adapted from Beasely & Butler, 2002)

Appendix 6

An example of the data analysis for determining fluid transitions in the written reports

Table 4. Instances of fluid transitions in a written report.

Test	Written Text	Instances of Fluid Transition
Dissolved oxygen	In Sample 1 an average measure of 5.8ppm was recorded, which is 17.14% below the accepted limit. Whilst not considered highly polluted, the water is on the verge of becoming polluted and drastic measures should be taken to increase the levels of DO in the water. Sample 2 had an average of 6ppm ,which is 14.28% below the limit, which is better than Sample 1, but still needs urgent attention. Sample 3 had an average DO of 2.95 ppm, 57.85% lower than the limit, though the fact that this is sea water should be taken into account and it therefore cannot be diagnosed as polluted on this factor alone.	Three instances where the results are used to determine the water quality in the three locations of the creek.
Faecal coliforms	Sample 1 had an average of 14252.4/100ml. This is a very high level of FC and should be treated immediately. No recreational use whatsoever should occur here. Sample 2 had an average level of 7631.25, which is highly polluted and should be examined. Overall the faecal coliform levels of the water are very polluted and should be improved thoroughly before recreational use.	Two instances of fluid transitions for Sample 1 and Sample 2.